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Spin-$\frac{1}{2}$

$$T_\mu = F_1(q^2)\gamma_\mu + F_2(q^2)\sigma^{\mu\nu}q_\nu + \gamma_5 F_3(q^2)\sigma^{\mu\nu}q_\nu$$

$F_1(0) = q$, $F_2(0) = a\,(e/2m)$ $F_3(0) = d$ (EDM)

$$H = \vec{\mu}\cdot\vec{B} + \vec{d}\cdot\vec{E}$$

	$\vec{B}$	$\vec{E}$	$\vec{\mu}$ or $\vec{d}$
P	+	−	+
C	−	−	−
T	−	+	−

	$\mu\cdot B$	$\vec{d}\cdot\vec{E}$
P	+	−
C	+	+
T	+	−
CP	+	−
CPT	+	+

EDMs $d_n < 3\times10^{-26}$ e·cm $[10^{-32}$ SM$]$

Sources for hadrons: d_u, d_d (charges), $\tilde{d}_u, \tilde{d}_d$ (chromoEDM) $\bar{\Theta}_{QCD}$

$\bar{\Theta}_{QCD}$ opp. in sign for p and n

STORAGE RING

if $\vec{E}, \vec{B} \perp \vec{B}$

$$\omega_a = \frac{e}{m}\left[a\vec{B} + \left(\frac{1}{\gamma^2-1} - a\right)\frac{\vec{\beta}\times\vec{E}}{c}\right]$$

$a_\mu = 10^{-3}$
$a_p = 1.7$
$a_n = -1.9$
$a_d = -0.1$

Choose E, Bs to set $\omega_a = 0$
For proton magic energy
$\vec{B}=0$, $\omega_a = 0$ at $p = 0.7$ GeV/c
R ~ 50 meters
Time dependence of out-of-plane spin direction.
Need relative position of counter beams
~ 10 mm/fill
or 1 pm/YR

$d_p < 10^{-29}$ e·cm

$d_p < 5\times10^{-25}$ e-cm from ^{199}Hg

ATOMIC $d_{^3He} \simeq 10^{-6} d_n$

$d_{^3He^{2+}} \gtrsim d_n$

Need spin coherence $\simeq 10^3$ s
need $\vec{P}_p \geq 80\%$
need 2×10^{10} p/fill 3 mA average current

$\delta p/p \sim 10^{-4}$

Systematics: vertical E-field

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$$\omega_{syst} = \frac{\mu \langle E_v \rangle}{\beta c \gamma^2}$$

minimize $R = \frac{a \mu \langle E_v \rangle}{d |\vec{E}| / \beta c}$

80 kV/cm

$$\beta = \frac{cB}{E} = \frac{3\times10^8 \ 0.1\ T}{80\times10^5\ V/m}$$

$$= \frac{0.3\times10^8}{.8\times10^7} = \frac{30}{8}$$

.01 T $\beta = \frac{3}{8}$

$$\gamma = \frac{1}{}$$

.85

$\gamma = 1.08$

$p = m\beta\gamma$

$= m \times .41$